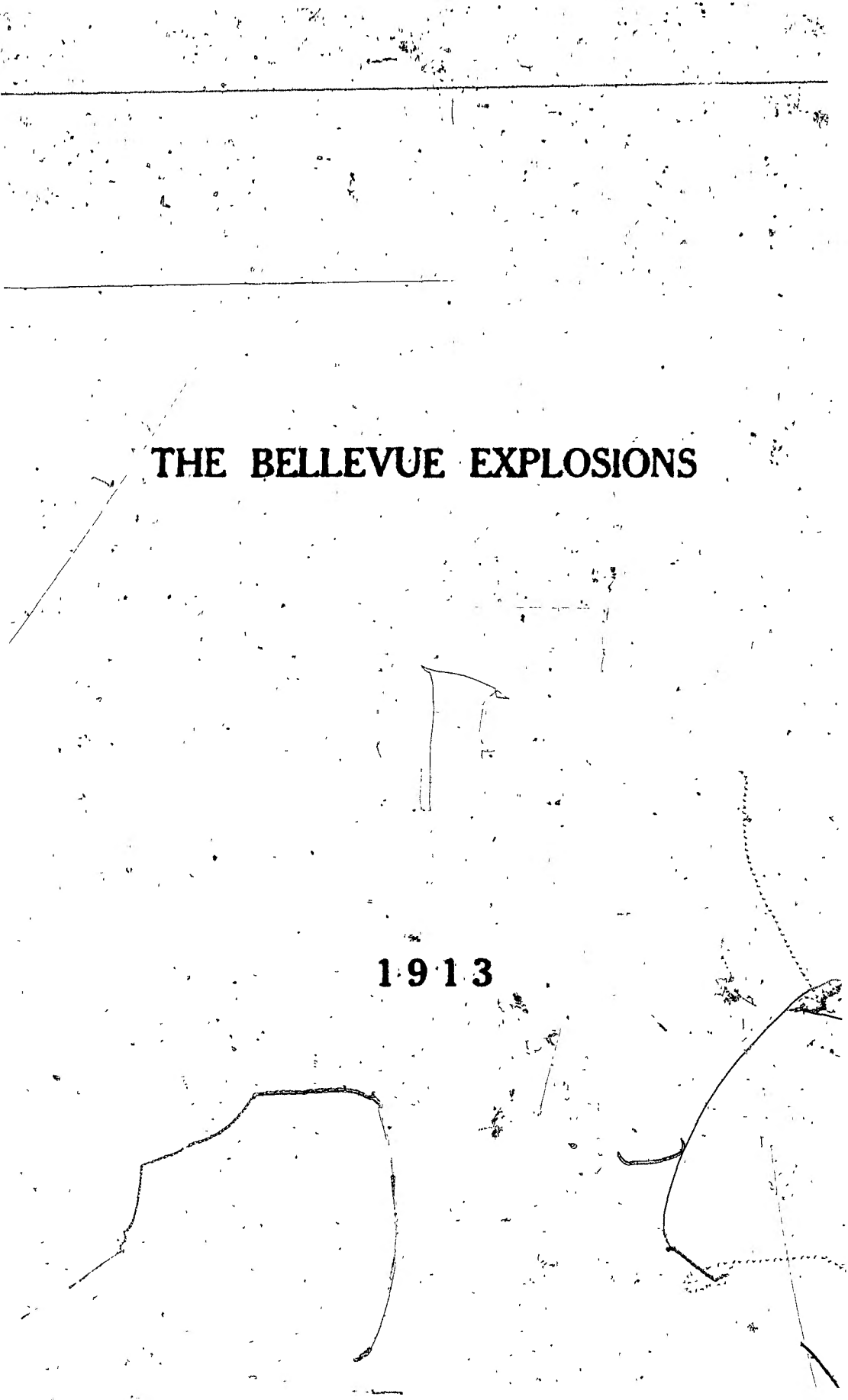
THE BELLEVUE EXPLOSIONS



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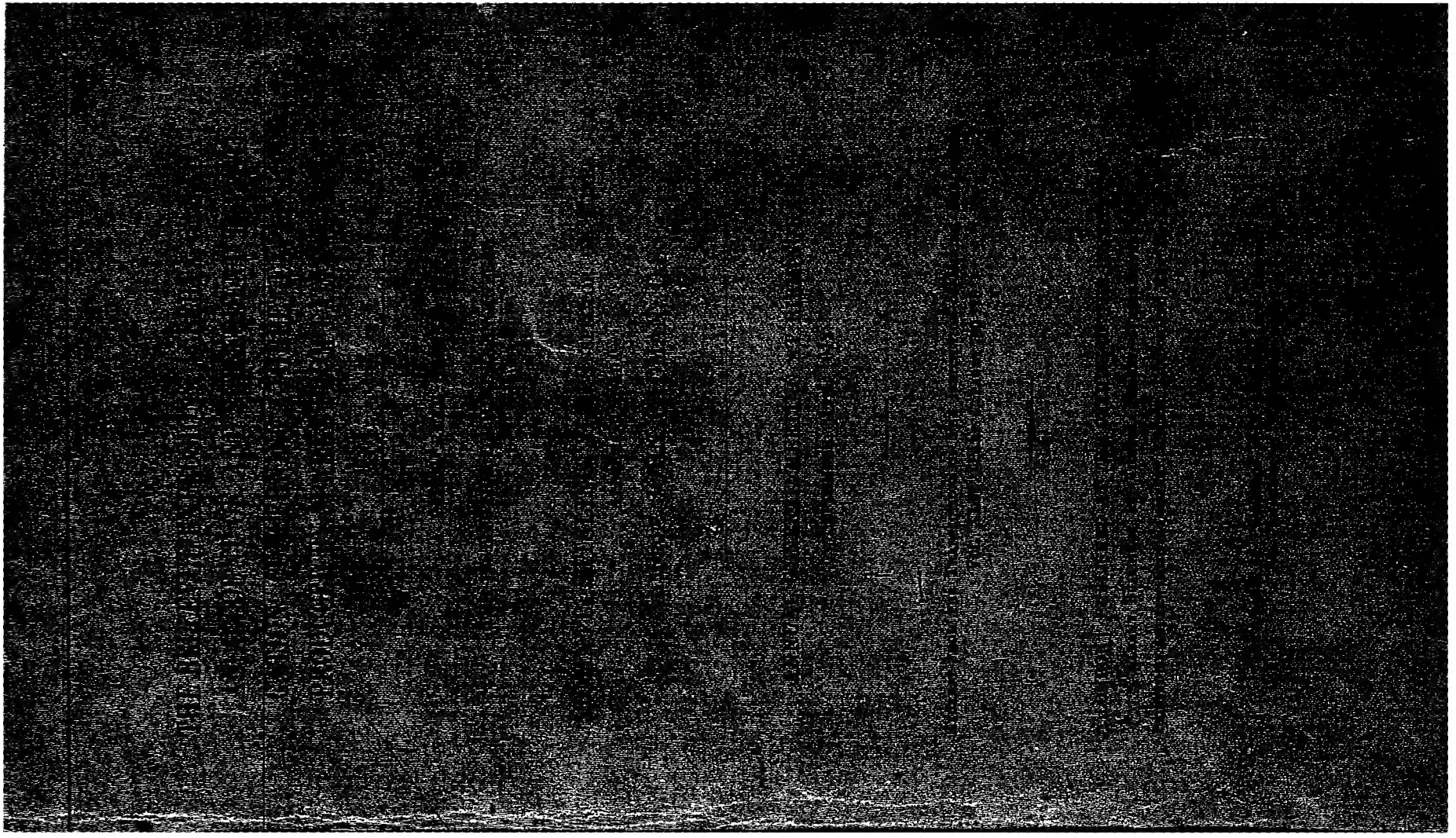

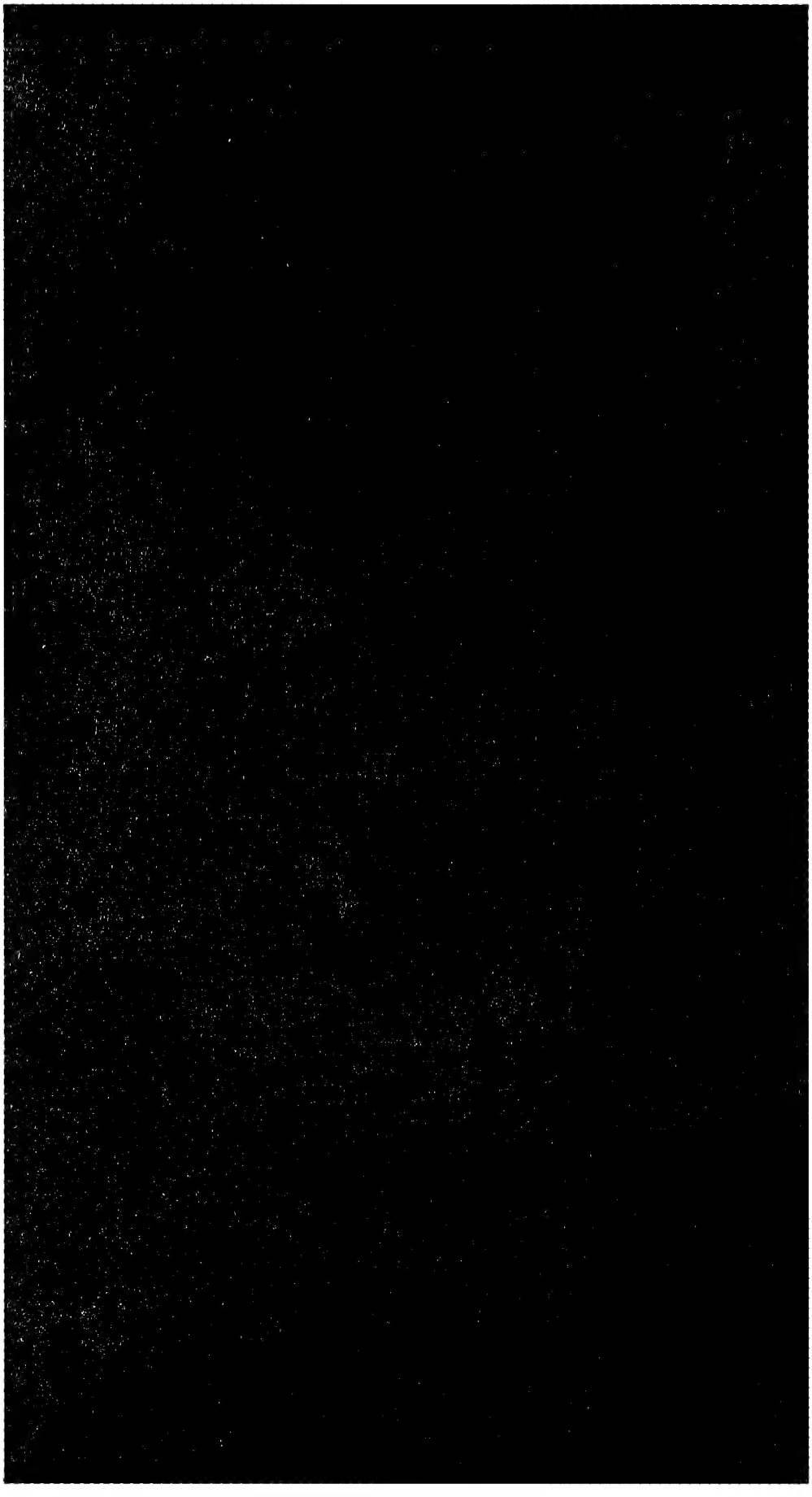

THE BELLEVUE EXPLOSIONS, ALBERTA, CANADA; AN ACCOUNT OF, AND SUBSEQUENT INVESTIGATION CONCERNING, THREE EXPLOSIONS PRODUCED BY SPARKS FROM FALLS OF ROOF.

By JOHN T. STIRLING, H.M. Inspector of Mines, Alberta, Canada, and Prof. JOHN CADMAN, D.Sc.

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Introduction.—As the circumstances attendant on a series of explosions at the Bellevue Mine during the years of 1910 and 1911 are of considerable importance and interest, the writers wish to place on record certain facts and the conclusions which they have deduced therefrom, in order to illustrate how explosions of considerable magnitude may originate from causes which appear to be somewhat unique in the history of mining.

The investigation which necessarily follows an explosion is always difficult, and usually hazardous, and although the point of origin may frequently be located within narrow limits, the exact source is often obscure: obscure, no doubt, because the investigators are limited in their choice of the igniting agent to the ordinary sources of heat which appeared likely to be forthcoming at the time when the ignition took place.

To those who have been called upon to investigate an explosion, how often has the suggestion of a blown-out shot, a defective switch, or a damaged lamp, run them into preconceived ideas of the cause of a calamity, when the real facts, if carefully and intelligently examined, lead to very different conclusions?

The writers hope to show that the explosions which they are about to describe were produced by the ignition of inflammable gas by sparks emitted from falling stones. The importance of such a source of ignition cannot be lightly overlooked. A few cases have already been placed on record and it is hoped that the discussion of this paper may be the means of thoroughly ventilating the subject.

In the removal of pillars—in the board-and-pillar working as practised in the North of England—a glow has been observed

on such occasions in the goaf when the roof has fallen in, and cases are known in which gas has been ignited by the spark from a pick. Indeed, a case is recorded by Mr. Miles of a collier igniting gas in 1880 at Pentre (Glamorgan) in this way, and doubtless there are many other instances.

In a paper* read by Mr. Edward Edwards before the South Wales Colliery Officials Association an instance is described of an explosion which occurred on November 8th, 1896, in the Maindy Pit of the Ocean Colliery Company, Limited. In the

FIG. 4.—GENERAL VIEW OF BELLEVUE MINE, SHOWING SCREENS.

appendix will be found some details of this explosion, which appears to have been clearly traced to an ignition similar to the one under consideration. In the discussion which followed the reading of Mr. Edwards's paper, several interesting references to ignitions of a similar nature were recorded.

One is apt to reject sparks of the kind, because one has seen sparks flying from a runaway tub, from a high-speed haulage, from a brake-wheel, and from the point of a miner's pick;

* "Notes on an Extraordinary Occurrence which took place at the Maindy Pit, Ocean Coal Company, Limited, on November 8th, 1896," by Edward Edwards, *Journal and Proceedings of the South Wales Colliery Officials' Association*, 1896, No. 12 (enlarged series), page 13.

but fortunately such sparks occur in atmospheres in which it would be perfectly safe to carry a naked light. Such evidence, then, does not prove that such sparks will not ignite fire-damp and air, but that the conditions under which mining is pursued to-day are more or less safe as regards such a source of ignition.

Bellevue Mine.—The Bellevue Mine, the scene of the present record, is one of a group of three mines worked by The West Canadian Collieries, Limited, of Blairmore, and is situated on the Crow's Nest Pass branch of the Canadian Pacific Railway, about half a mile east of Hillcrest Station, and about 2 miles

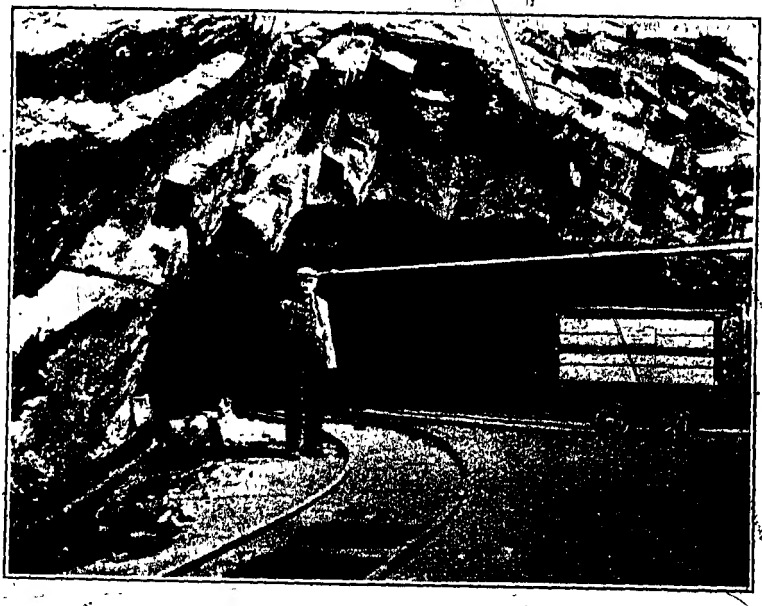

FIG. 5.—ENTRANCE TO BELLEVUE MINE.

east of Frank. Fig. 4 in the text is a general view of the mine, which employs about 200 men on three shifts, divided as follows:—day-shift, 80; afternoon-shift, 60; and night-shift, 40. The output is from 800 to 1,000 tons per day. The entrance to the mine is by an opening in the hillside, as shown in Fig. 5 in the text.

Four seams, known as Nos. 1, 2, 3, and 4, are intersected at distances 135, 258, 350, and 500 feet respectively from the mine entrance. The seams dip at an average inclination of 45 degrees.

No. 1 Seam has an approximate thickness of 13 feet, with a hard siliceous roof, and has been extensively developed. It was in this seam that the explosions occurred.

No. 2 Seam, with a thickness of some 12 to 13 feet, was opened up by a level 3,800 feet long, and has only been worked to a small extent.

Nos. 3 and 4 Seams have not been developed, only some 2,000 feet of roadway having been driven in No. 4 Seam, whilst No. 3 Seam remains untouched. These seams, therefore, have no bearing upon the explosions.

The workings of the mine are reached from a cross-measure drift which intersects No. 2 Seam at a distance of 120 feet from the side of the hill. From here a level driven in No. 2 Seam at a distance of 3,800 feet meets a fault, and a cross-measure drift is set back to recover No. 1 Seam. At the point where the drift cuts the seam, a thickness of 14 feet was found. A level, 10 feet wide by 7 feet in height, has been driven along the strike of the seam for a distance of 5,000 feet from the cross-measure drift. The total distance from the entrance of the mine to the far end of this level is, therefore, some 9,000 feet (Fig. 1, Plate XI.).

Parallel with and 40 feet to the rise of the main level is an airway or counter gangway 6 feet wide and 6 feet high. At intervals of from 30 to 150 feet rises or shoots, 20 feet in width, have been driven up, with connecting roads every 50 feet, thus cutting up the area generally into pillars. The shoots in No. 1 Seam are numbered from the cross-measure drift from No. 1 to 127 to the extreme in-bye end.

The development of the mine has not been followed on systematic lines, so that very irregular pillars and openings are the result. From shoots Nos. 1 to 28, rooms 20 feet wide were driven to the rise, and the pillars extracted by a retreating method, a row of two pillars being left to protect the main levels. Shoots 28, 36, 41, 45, 52, 58, 62, 67, and 71 were driven to the rise for a distance of 320 feet, and, with a view to getting a better class of fuel, level roads were driven at 50-foot centres from both sides of each of these shoots. Some time prior to the first explosion, the roof where the pillars had been extracted in the neighbourhood of shoot 29 caved in to the surface. This method of working the coal parallel to the

strike was ultimately abandoned, and roads were again driven to the rise from shoot 75 onwards.

It was the intention to open out the work with regularity, with rooms to the rise 20 feet wide, with pillars 30 feet long, and with cross-cuts measuring 6 feet by 6 feet driven through the pillars every 40 feet. The unsystematic way in which the work has been followed up has no doubt indirectly some connexion with the explosions.

The rooms to the rise have in some cases been driven to the outcrop, as in shoots 45 and 81, which intersected the surface in the former case at a distance of 345 feet from the main level, which was maintained as a second outlet to the surface. The latter was driven up 500 feet from the main level to the crest of an assymetric anticline, from which a road was put through to the surface.

It will be seen that the method of working resolved itself into the driving of wide rooms to the rise, and such portions of the ribs extracted as could be obtained before the roof collapsed, or showed signs of collapse. The roof being of a hard siliceous nature, wide openings were thus left in the waste.

No. 1 Seam has approximately the following section taken at shoot 102:—

Roof: Hard siliceous Sandstone.

	Feet	Inches		Feet	Inches.
Coal	1	4	Coal	2	1
Band, siliceous		4	Soft dirt		1
Coal	5	6	Coal	4	3
Band, bone coal		1	Hard floor		

Approximate analyses of various samples of the seam and dust found in the dry portions of the mine were made by Mr. Alexander Clubb, B.Sc., and were found to be as noted in Table I.

TABLE I.—APPROXIMATE ANALYSES OF SAMPLES OF THE SEAM AND DUSTS FOUND IN THE DRY PORTION OF NO. 1 SEAM.

No.	Sample.	Ash	Moisture	Fixed Carbon	Volatile Matter.	Sulphur.
		Per cent	Per cent	Per cent	Per cent	Per cent
1	Coal from room 76 ...	10·9	0·9	66·7	18·9	2·6
2	Coal from room 91 ...	13·8	1·0	62·8	19·4	3·0
3	Coal from room 110 ...	10·9	1·0	67·5	17·2	3·4
4	Dust from shoot 46 ...	13·7	1·5	67·0	14·9	2·9
5	Dust from counter of gangway, room 90 ...	12·3	1·2	65·2	18·6	2·7
6	Dust from room 110 ...	12·1	1·5	67·5	15·5	3·4
7	Dust from shoot 52 ...	15·7	1·4	67·6	12·5	2·8
8	Dust from room 109 ...	13·2	1·0	64·2	18·2	3·4

Haulage.—The coal mined from the rise working is dumped into the shoots, where it gravitates to the main level. At this point doors are fixed to trap the coal in natural bunkers, from which it is loaded into tubs upon the main haulage-level. The method of haulage adopted is by locomotives driven by compressed air, high-pressure pipes (1,200 pounds per square inch) being laid along the haulage-road to shoot 124, with charging stations for supplying the locomotive tank at shoots 26, 37, 84, and 124. A low-pressure (80 pounds) air-supply was also carried along the haulage-road to shoot 110 for the purpose of supplying power to the rock-drills.

The tubs each carry 3 tons of coal, and thirty to thirty-five tubs form a train for each locomotive.

Ventilation.—The ventilation is produced by a 60 by 78-inch Sirocco forcing fan, which is capable of producing 65,000 cubic feet of air per minute, with a 2-inch water-gauge, when running at a speed of 185 revolutions per minute. The fan is electrically driven, and is fixed at the surface of shoot 2 in No. 2 Seam. The air then enters the mine at shoot 2, and is directed by means of doors into the main level in No. 1 Seam, which forms the main intake for the district under consideration. A split of 20,000 cubic feet of air passes up shoot 46, where it ventilates the workings off this shoot, passing thence through the old working to the top of shoot 81, where it is regulated and meets the main return. The main air-current passes to the face of the haulage-level, from which it is conducted round the working-places, and finally finds its way to the main return in shoot 81.

It will be noted that the general method of working does not lend itself to the very efficient ventilation of the working-places, and of the goaf-spaces in which inflammable gas accumulates. Further, the type of stopping built between intake and return permitted large leakages, which seriously handicapped brisk ventilation. Although the general defect in the ventilation scheme did not contribute to two of the explosions about to be described, as the fan was not running, the defect will be apparent when considering the second explosion, and the question has an important bearing upon the recurrence of similar disasters.

The Explosions.—So far as the history of ignitions of gas in

the mine is recorded, a few ignitions were traceable to direct ignition from open lights prior to the introduction of safety-lamps into the mine in August, 1906. The following is the record:—

August 7th, 1906.—A miner ignited gas in a rise working with an open light in working just beyond the rock-tunnel which proves No. 1 Seam.

August 20th, 1906. A miner ignited gas in an old gangway off shoot 55 with an open light.

August 25th, 1906.—Four miners burned by an ignition of gas from an open light in a rock-tunnel in No. 1 Seam.

After the ignition of August 25th, 1906, Wolf safety-lamps were introduced throughout the mine, and no further ignition occurred until the first explosion of the series here described. The explosions occurred as follows:—

(1) October 31st, 1910, at 12 a.m.—No one underground at the time.

(2) December 9th, 1910, at 7 p.m. Thirty lives lost; forty-seven men in the mine at the time.

(3) About January 28th, 1912.—No one underground at the time.

No. 1 Explosion.—On the morning of Monday, October 31st, 1910, an explosion of some violence occurred, but at the time there were no persons in the mine, it being a general holiday—"Thanksgiving Day." Work was suspended at midnight on the previous Saturday, and no one had been in the mine since. The fan had been stopped for 9 hours (7·30 a.m. to 4·30 p.m.) for repairs on Sunday, the 30th. That an explosion had happened was realized by the electrician, who observed a dense cloud of smoke and black dust being ejected from the outcrop mouth of shoot 81, followed some moments afterwards by a further volume of dust from shoot 45.

An exploration party was at once organized, and an examination made of the mine, when the evidence of an explosion having originated in the neighbourhood of shoot 71 became apparent. A great deal of damage and *débris* blown in various directions was discovered, and immediately above the counter-gangway pillar between shoots 61 and 71, a large fall of roof was discovered. This cave was about 4 feet thick, and extended to the rise for a distance of upwards of 80 feet.

So far as evidence collected at the time went, it pointed generally to this fall as being the point of origin. The direction of force was traced by Mr. Elijah Heathcote, the District Inspector of Mines, to whom the writers are indebted for this

information. At the entrance to the mine there was no sign of the explosion, and it was not until shoot 14 was reached that any evidence of the explosion was manifest. From shoot 14 in-bye, all the electric lamp-bulbs showed a thick coating of mud and dust, and several were broken. Tubs were coated with from 2 to 3 inches of mud, plastered all over the in-bye side. In the neighbourhood of shoot 58, evidence of out-bye force was available, props were displaced, and material dislodged. At shoot 65 much disturbance appeared, and at the bottom of and in shoot 67 evidence of flame was visible in the form of coking on the in-bye side of the props. From shoots 67 to 71 there was much evidence of flame, coking being observed on the out-bye side of the props. The writers do not attach any importance to the flame as showing evidence of direction of force. At the pass-bye near shoot 104, a set of empty tubs was standing, the two in-bye ones being blown across the road-way off the track. There was evidence of the force having come down shoot 104 and out-bye from this point. There was no disturbance on the main level in-bye of shoot 104. The general physical indication, however, appeared clear to Mr. Heathcote that the point of origin was in the neighbourhood of the top of shoot 67, that the explosion passed both in-bye and out-bye from this point, and also down the shoots to the main haulage-level and up shoot 81 to the surface.

It is quite evident that, under the system of ventilation in vogue, accumulations of gas would occur, particularly in the unventilated goafs lying to the rise between shoots 45 and 81. The stoppage of the fan for 9 hours would permit gas to accumulate there, and the restarting of the fan would not for a time reventilate the area. Given a means of ignition, the explosion can be clearly established as originating here. To account for the explosion was indeed a serious problem, and although Mr. Heathcote boldly attributed the occurrence to an ignition caused by sparks produced from falling roof, the management and mining public generally were not inclined to accept the theory upon such indirect evidence. It was, of course, not surprising that in the circumstances other suggested means of ignition were put forward, such as explosives left smouldering, matches left in the mine, etc., but no evidence was forthcoming during subsequent careful investigation.

The cause of the explosion was generally looked upon as shrouded in mystery, and the true lesson of its occurrence was not learnt.

On the whole, the mine is a wet one, although dust can be observed in some of the workings, and whilst this explosion was primary and chiefly due to fire-damp, no doubt a little fuel was added to the flame in the form of dust from some of the upper workings. It is interesting, however, to note that the effects of the explosion were local when compared with the mine as a whole.

No. 2 Explosion.—This explosion occurred at 7 p.m. during the afternoon-shift of December 9th, 1910, there being forty-seven persons underground at the time of the explosion. Thirty of these men were killed, together with one of the rescue-party wearing a Draeger apparatus.

The men were employed as follows:—Three men were working in a stone-drift at the top of shoot 109 through the anticline which was being driven for the purpose of providing another outlet; two each in shoots 118 to 127 inclusive; two in shoot 129; eight loaders and one bratticeman on the main level between shoots 118 and 129; four with the compressed-air locomotives; four timber-packers in shoot 52; one waggonway-man; two door-trappers: one overman; and one fireman: the overman being at shoot 84 and the fireman at shoot 120 when the explosion occurred. As a result of the explosion, the overman, waggonway-man, one man in shoot 118, the two men in shoot 119, the fourteen between shoots 121 and 127, the two in shoot 129, the four timber-packers, the four loaders, and the bratticeman lost their lives.

Rescue-parties from British Columbia, inadequately fitted with breathing-apparatus—for they had only two sets of 2-hour and two sets of 1-hour apparatus—were at the mine within 7 hours after the explosion, and rendered very valuable service, despite the unfortunate fact that one man lost his life whilst wearing the apparatus. Two men wearing apparatus—one Mr. Robert Strachan, the Inspector of Mines for British Columbia—penetrated through a zone of afterdamp in the main level, and ascertained that a number of men were alive in the fresh air beyond. Precautions were then taken to prevent the after-

damp from being driven on to these men, which undoubtedly would have happened in the anxiety to reventilate the mine immediately, had not the information been obtained. The apparatus was in this way utilized for the saving of some fourteen lives. An effort was at one time made to bring the victims through the zone of afterdamp, but the number of appliances available was totally inadequate. It was during this attempt that a member of the rescue-party (Alderson) lost his life. Exactly what failed in the apparatus is not known, although the writers suspect that some of the joints must have been leaking and permitted afterdamp to get inside.

From an examination of the mine after the explosion by one of the writers, the indication of force showed the explosion to have radiated from the rise working between shoots 71 and 75. The general direction of force was somewhat indefinite, although considerable damage was manifest in some parts of the workings. The point nearest the entrance to the mine where damage was visible was the bottom of shoot 43, where the boards forming the shoot were dislodged. No further disturbance was observed until shoot 53 was reached; but from this point in-bye the general direction of force appeared to be out-bye in the return airway and parallel rise roads and in-bye on the main haulage-road. The bottoms of most of the shoots appeared to have been blown down, although it is somewhat difficult to accept this evidence in a seam dipping with an inclination of 45 degrees. The maximum downward force appeared in the neighbourhood of shoot 76. The evidence of mud thickly plastered on the tubs and timbers appeared clearly indicative of the direction of force. Beyond shoot 100 on the main level there was no disturbance. Fig. 1 (Plate XI.) is a plan of the mine, and shows the general direction of the force as observed. It appeared quite clear that this explosion originated in the locality of shoot 74. At the top of this shoot, and extending for some distance, a large fall of roof had occurred. At this point it will be noted that there is also every opportunity for an accumulation of gas being present in this open goaf; and, given a source of ignition here, an explosion of fire-damp would account for all the phenomena observed.

A public enquiry was held into the cause of this explosion in December, 1910, and January, 1911, and much evidence was adduced as to the cause of the disaster. For want of a more

definite solution, the jury favoured the view of one mining engineer who suggested that the explosion was due to what he termed "his 'percussion' theory," a suggestion which can be dismissed at once, and which will not bear the most slender investigation.

In the first place, there was no evidence to support such a theory, even if such a mode of origin were possible, and as some of the instances quoted in support of the theory were so inaccurate, and the reference so misleading, it would be a waste of time to quote even the reasons advanced in support of such a theory.

There is no doubt that the explosion was caused by an ignition of fire-damp, ignited by sparks emitted from the falling roof.

No. 3 Explosion.—After the explosion of December 9th, 1910, a general strike occurred throughout the Crow's Nest Pass district, and the Bellevue Mine was not re-opened. Somewhere about January 28th, 1911, a further explosion occurred, which did much more damage than on either of the previous occasions. The exact date is somewhat uncertain, as the explosion was not actually observed.

An official inspection was made of part of the workings on January 25th, and a new manager was appointed to the mine on January 28th, a few days after which the effects of the third explosion were noticed. The fan had been standing since shortly after the explosion of December 9th, 1910, but was set running from January 13th to the 25th, 1911, in order to prepare for the Government inspection. It was, however, stopped again after the inspection.

That a third explosion had occurred was observed, first by a fireman going into the mine for some tools on January 30th, when he encountered afterdamp. A subsequent examination revealed that the explosion had originated from the neighbourhood of rooms 89 and 90. At this point a heavy fall of roof had occurred, and the area was a very suitable one for gas to have accumulated during the period when the fan had been standing.

The mine remained untouched after this explosion for some months, owing to the strike, and the writers made a careful examination of the workings during August, 1911. The magnitude of the explosion within a limited area was very manifest,

and although it was difficult to distinguish the evidence of the explosion of December 9th, 1910, from that of the later one, by a careful comparison of data and notes it was possible to differentiate between the two.

The No. 3 explosion emanated from about shoot 90, radiating in several directions, and causing considerable damage on the main level at the bottom of shoot 102. At this point fifteen tubs, each approximately 2,000 pounds tare, and each carrying over 5,000 pounds of coal, were standing in the shunt. The first four tubs of the set were blown out-bye a distance of 40 feet, one

FIG. 6.—MICROSCOPE-SECTION OF ROOF ROCK. MAGNIFIED 40 DIAMETERS.

being turned over on its side, and another upended. Of the other eleven, nearly all were off the rails, one turned upon end, one turned over on its side, and another with the side blown out. The writers instance this example to illustrate the extent of the force, which was certainly greater than in either of the previous explosions.

The writers made a careful examination of the seat of the ignition, and ample evidence of flame was obtained, as also evidence of pitting in the form of globules of coke-dust splashed up against timbers was observed radiating from this area. Al-

though the writers do not attach much weight to this, it is worthy of note, particularly as the general evidence of direction clearly pointed to this place as the starting-point, and they have observed similar pitting of coke-dust around the area of ignition of fire-damp in other cases.

Cause of the Explosions.—An experiment was tried in the mine with the hard siliceous roof which Mr. Heathcote had suggested might cause sparks sufficiently intense to ignite fire-damp. A large lump of the rock, weighing some 60 or 70 pounds, was lifted and dropped into one of the shoots, on the

FIG. 7. MICROSCOPE-SECTION OF ROOF ROCK. MAGNIFIED 180 DIAMETERS.

floor of which lay some of the fallen roof. As the lump rolled down the shoot, a brilliant display of sparks was observed. Specimens of this roof rock were therefore submitted to a careful examination by one of the writers. When a specimen is struck a glancing blow with a hammer, the surface of percussion glows red hot for the instant, which is probably due to the sparks generated by the friction between the steel and the sand-grains igniting the powdered bitumen and the gas liberated, both by the fine pulverization of the bitumen and by the frictional

heat. On a further examination, the rock was found to contain carbonaceous matter, as will be described later. Again, when two small pieces of the stone are struck one against the other, sparks are seen, the intensity of the sparks varying with the energy applied. To obtain a play of sparks, a steel flint-mill was used, and sparks of sufficient intensity were produced to ignite very readily coal-gas or methane.

A further series of experiments were then tried, in which the rock was attached to a spindle capable of revolving at 200 to 300 revolutions per minute, and by allowing another piece of the rock to come into contact with the revolving piece, sparks of sufficient intensity could be produced to ignite coal-gas and methane.*

The writers are indebted to Mr. Frank Raw, M.Sc., for a microscopic examination of this rock, and for the photographs of the microscope-sections shown in Figs. 6 and 7 in the text.

"The rock is a bituminous sandstone, very fine and even in texture, but clearly made up of distinct black and grey grains, giving the whole a dark-grey colour, indistinctly, though certainly, laminated thin layers of black occurring in it, along which it splits most readily. A hand-specimen roasted in a clear gas-flame for some minutes yielded on one side patches of glossy black coke, whilst on the other side the black colour had been discharged, doubtless through oxidation, leaving a pale-grey very fine-textured sandstone."

"A thin section of the rock under the microscope shows a fairly even-grained texture, and consists chiefly of colourless grains, which are mixed with a large proportion of grains of various shades of dull yellow and brown to black. The colourless grains are chiefly quartz, which comprises about 50 per cent. of the rock, together with a few felspar granules and abundant grains of micro-crystalline rocks, mostly felsite. The lightest coloured grains are also of micro-crystalline rocks; but the bulk of the brown grains, perhaps a sixth of the rock-mass, seem to be of carbonaceous material which exert no action upon polarized light. Some of them show traces of organic structure. The blackest grains (brown in reflected light), small and very irregular in shape, forming strings along the bedding-planes

* These experiments were repeated at the meeting.

between the other constituents, are doubtless bitumen, and have clearly yielded under pressure. Besides these definite areas of "bitumen," the grains throughout the rock are defined and separated one from the other by brown lines, which are most probably due to a bituminous cement, filling all interstices, and thus rendering the rock very resistant; and it is not improbable that the marked flame-producing property of the rock may be due in part to this perfect cementation, which limits the frictional heat to the surface."

Several samples of mine air were taken, which on analysis showed the presence of fire-damp. One sample, for the analysis of which the writers are indebted to Dr. Wheeler, showed the presence of ethane. The results of the analysis of this sample are given in Table II.

TABLE II.—ANALYSIS OF MINE AIR FROM BELLEVUE MINE.

		Per cent
Carbon dioxide	(CO_2)	0·15
Oxygen	(O_2)	19·30
Methane	(CH_4)	4·35
Ethane	(C_2H_6)	0·30
Nitrogen	(N_2)	75·90
Total		100·00

The amount of fire-damp present in several of the other samples was not sufficient to admit of the presence of other paraffin hydrocarbons being determined.

It is of interest to note the presence of ethane in the above sample. As the ignition-temperature of the paraffin hydrocarbons appears to fall slightly as the series ascends, the presence of this higher hydrocarbon in the fire-damp would lower the temperature of ignition, and thus render more easy the ignition of gaseous mixtures by sparks from falls of roof.

It is clear, however, that sparks of sufficient intensity can be produced by rubbing together pieces of the roof of No. 1 Seam to ignite methane, which has an ignition-temperature—according to Dixon and Coward—of from 556 to 700° Cent., and as other hydrocarbons have been shown to be present, the temperature of ignition will be less, and an explosive mixture will be more readily ignited.

Wheeler and Burgess, in their research on "The Lower Limit of Inflammation of Mixtures of the Paraffin Hydrocarbons with

Air,"* showed that the length of the spark necessary to ignite the lower-limit mixtures was not material, provided that the temperature was adequate.

By the abrasion of two surfaces of the rock in question, it appears that a definite amount of energy has to be exerted before sparks of sufficient intensity can be produced to bring about ignition. The writers are satisfied, however, that they have established the fact that sparks can be produced by falls of roof in the No. 1 Bellevue Seam sufficient to bring about the ignition of inflammable gas; and as subsequent examinations after each explosion showed that falls did occur, in which large masses of the roof fell, in areas where gas was in all probability present, it seems perfectly clear that the cause of the three explosions at Bellevue has been satisfactorily explained.

To avoid such calamities in the future is a very difficult and serious problem. The present method of working lends itself to irregular falls in open and ill-ventilated goaves. It is impossible in the present method of working to prevent falls in the open goaf, and it is further practically impossible to ventilate satisfactorily all the goaf-spaces under the system in operation prior to these explosions. A method customary at many mines in the Crow's Nest Pass in working outcropping seams is now being adopted of putting shoots through to the surface at frequent intervals for the purpose of freeing the upper goaf-areas of inflammable gas. Such a method is applicable only during such time as outcrop-workings are in progress, and at the most can only be said to be a temporary expedient. A form of working which permits of the filling of the goaf-space appears the most satisfactory solution of the problem. Although a practical solution of the difficulty, the introduction of such a method is connected with commercial questions which it is not the intention of the writers to discuss.

It is well known that the origin of a number of explosions in this country and elsewhere has remained obscure, and whilst it is not suggested that sparks from falling roofs are by any means common, it is a subject which deserves the serious attention of all employed in mining.

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* *Journal of the Chemical Society, Transactions*, 1911, vol. xcix., page 2,013.

APPENDIX.—EXPLOSION AT THE MAINDY PIT, GLAMORGAN, CAUSED BY SPARKS PRODUCED DURING A FALL OF STONE.

An explosion occurred at the Maindy Pit, belonging to the Ocean Coal Company, Limited, on November 8th, 1896, which has been described by Mr. Edward Edwards in a paper published in the *Journal and Proceedings of the South Wales Colliery Officials' Association*.*

The accompanying plan and section (Figs. 2 and 3, Plate XI.) explain the circumstances. Gas was now and then known to occur on the top of a fall. The seam had not been worked for a period of 12 months before the explosion occurred, and there was in consequence little coal-dust on the roadways. That an explosion had taken place was observed by the *débris* and havoc wrought in the roads, and the fall was subsequently allocated as the point of ignition. At this place it was found that a recent fall had taken place, and as gas was present in the hole, it was thought that sparks had been produced by the fall which ignited the gas.

By rubbing pieces of the rock together sparks were seen. Mr. W. J. Heppell described some experiments which he had conducted with the stone. A box measuring 3 feet by 3 feet 3 inches, with a shaft passing through, was used, and a spindle attached, to which stones were fixed. Gas was brought from the pit and explosive mixtures obtained. One stone was fastened to the spindle and the other to the box. Explosions occurred when the stones struck, and the experiments were witnessed by a number of people. Dust was also tried, but no ignition occurred.

Mr. A. M. HENSHAW (Talk o' th' Hill Colliery) said he thought that there could be no doubt, after what had been stated by the writers of the paper, and the experiments that had been witnessed, that the Alberta explosion was caused by sparks from the falling rock. The conditions necessary in the nature of gas-accumulations, owing to the cessation or inadequacy of ventilation, were present on at least two of the occasions, and the evidence as to the falls of roof might be accepted. The peculiar, and fortunately rare, character of the rock in respect to its sparking property had been demonstrated, and in the absence of any person or other means of ignition in the pit at the time of the explosions, they were enabled to thoroughly agree with the writers of the paper in their conclusions.

Unexplained explosions might, he feared, be due to the same cause in some other instances, and a closer examination into the nature of the roof-rocks demanded attention when considering the cause and prevention of such accidents. It was fortunate that conditions similar to those prevailing at the

* 1896, No. 12 (enlarged series), page 13.

Alberta mine were rare, but he was reminded of the explosion at the Orrel Colliery, Wigan, in 1902, which he considered was caused by the spark from a shovel striking the roof. In the evidence at the inquest it was shown that gas had accumulated in a working-place, and a collier named Draper went into the place in the dark to drive out the gas by swinging his shovel. Another man heard him strike the roof; there was a flash, and then the explosion. Draper himself, before he died in the Infirmary, told the manager of the colliery that he saw sparks when his shovel struck the roof, and that the explosion followed instantly. The jury were unable to find how the gas became ignited.

The verdict in the Alberta case was incredible. The jury, influenced by evidence given by Mr. James Ashworth, found that the explosion was caused by percussion of air, due to the caving-in of the roof. Such a theory need not be seriously discussed, but that gentleman, in order to support his theory, made much capital of the explosion in 1901 at the Talk o' th' Hill Colliery, with which he said he was familiar. He (Mr. Henshaw) was not aware that Mr. James Ashworth had ever visited the colliery during the past 25 years, and he certainly had not done so at the time of the explosion. Mr. Ashworth asserted that this explosion was caused by a fall of roof and percussion of air, and gave particulars which were altogether erroneous. It was proved beyond question that the Talk o' th' Hill explosion was caused by "gob-fire."

However mysterious the cause of certain explosions might be, the air-percussion theory might be totally disregarded, and the Alberta explosion in particular, notwithstanding the finding of the jury, might without further question be attributed to sparks from a fall of roof, as advanced by the writers in their excellent paper.

The members were particularly indebted to Prof. Cadman for his active interest in questions of the kind, and for the valuable scientific and experimental work the University authorities were always so willing to undertake in order to promote the study of difficult problems exercising the minds of mining engineers.

Dr. W. N. Atkinson (H.M. Inspector of Mines, Cardiff) expressed his appreciation of the paper and of the work that Prof.

Cadman had done in connexion with those explosions. There was abundant evidence that sparks of all sorts would ignite gas. The explosion to which Prof. Cadman had referred in South Wales appeared to be quite as well substantiated as being caused by sparks from a falling rock as the Alberta explosions. That explosion had been investigated by one of his colleagues. He (Dr. Atkinson) had discussed the matter with him, and there appeared to be no doubt as to the cause of the explosion: it could be demonstrated in a similar way to that in which Prof. Cadman had shown them, that the stone which fell in that case produced the sparks which ignited the gas. Explosions had also been caused by sparks from miners' picks. In two or three cases of such ignitions which had come under his personal notice he could not be positively certain as to the cause, because there were other possible means of ignition; in one case, for instance, the men were working with naked lights. There had been cases of ignition of gas by the cutting of bar machines, where there was a possibility of electricity coming into play. But, taking all cases that were known, there appeared to be no possible doubt that an explosion might be started by a fall of roof. It had also been proved abundantly that electric sparks would ignite gas. The recent explosion in South Wales was caused without doubt by the sparks from signalling wires, which had a voltage of 11½. Afterwards, gas was ignited experimentally by only 4 volts.

What could be done to prevent such explosions was, as Prof. Cadman said, a very difficult problem. It appeared impossible to prevent the production of these sparks, and the only other means appeared to be to prevent gas being present where the sparks might be produced.

There was also another view of the matter which occurred to him: although it was absolutely proved that explosions might be caused in that way, in investigating an explosion such a cause ought to be the very last that was thought of. Only after having exhausted all other possible causes of ignition should sparking be considered. Otherwise, it would be very easy to say: "There has been a fall of roof, and there must have been a spark to have fired the gas." This attitude would distract attention from other much more likely causes which were generally present.

Mr. F. H. WYNNE (H.M. Inspector of Mines, Newcastle, Staffordshire) said that he wished to add a word or two to what Mr. Henshaw had said with reference to the paper. Like all other papers with which Prof. Cadman had been connected, it had been thoroughly practical and original. The theory of serious explosions arising from the clashing of rocks had not, so far as he knew, been previously considered seriously. After what they had seen, they could have no further doubt about it.

Dr. Atkinson had mentioned other methods of igniting gases by sparks, of some of which they had already heard, and had stated that the question of the prevention of ignitions by falling rocks was a difficult one. It appeared to him that there was only one method of preventing them, and that was by the complete packing of the seam, either with dry stones or with hydraulic packing. At the same time, by that process he thought that they could do away largely with the danger of gob-fires in thick seams, which had become such a serious question.

Mr. WILLIAM SAINT (H.M. Inspector of Mines, Stafford) mentioned a case, which had come under his observation in South Wales, where two men were set to enlarge a heading in a coal-mine. They had drawn the collar of a setting of timber and let down about 20 to 30 tons of rubbish. While drawing another collar, a further fall took place on the top of the first one, and both those men, who were standing facing their work on the intake side of the air-passage, observed a flash immediately the second fall touched the first. One of the witnesses described the flash as like that which occurred when benzoline was thrown on a fire. In the cavity there were two small bands of hard siliceous rock, one 8 and the other 2 inches thick, separated by about 2 inches. On the lower side of the heading there was a break in the roof, which two days after the occurrence was giving off fire-damp. The men reported the fact to an official, but on examining the cavity the official did not find any gas, and it was only on putting a lamp into the break two days afterwards that gas was discovered. The volume of air passing was considerable, and was said to be 12,000 to 15,000 feet a minute.

He had himself seen an abundance of sparks produced by rubbing vigorously together two rocks which had been obtained

from the roof of a coal-seam in one of the steam-coal pits of South Wales.

Mr. R. McLaren (H.M. Inspector of Mines, Airdrie) said that it was no uncommon thing in some collieries to have sparks from hard rock, as mentioned by the authors. In the first instance which came to his mind the men had bored a shot-hole in what they called in Scotland "kingle," a stone not unlike that which had been produced by Prof. Cadman. The men only bored the hole a short distance in, and put in a charge of gunpowder; in order to stem the hole, one of the men put in a too hard piece of kingle rock, and while stemming it up an explosion occurred. It had occurred to himself and the manager that probably it was due to sparks caused by the two portions of stone in the hole rubbing against each other. Experiments were made, and in every case by rubbing those two hard kingle stones together they got sparks, showing that it was quite possible that in a fall such as that described by Prof. Cadman sparks would occur; and, if explosive gas was present, there must be an explosion. He thought that the members were very much indebted to the authors for having brought that fact so vividly before them in the experiment which they had seen, and also for giving them so valuable a paper. In considering cases of explosions of fire-damp this was another source of danger which had to be reckoned with. There were many sources from which sparks were obtained, and this added another to the list. He thought that it would be well for them, before coming to hasty conclusions on any matter relating to the cause of an explosion, to exhaust all enquiries: not only should they consider the question of sparking by electricity and other causes, but they should also keep in mind the fact which had been before them, and had been proved conclusively by himself on many occasions, that another source of danger came in, namely, sparks caused by the rubbing of one stone against another. How explosions were to be avoided in a goaf was a very difficult problem.

Many years ago, a manager was proceeded against for permitting gas to be in the goaf. The case failed because it was not possible to remove the gas. The method of working was stoop and room, and in stooping the goaf was left behind in coming back to the shaft-bottom. The roof fell, and the gas collected in the cavities.

In a seam lying at 45 degrees, it was not a difficult matter to have openings made to the surface along the line of outcrop, when the workings were going to the rise and near the outcrop, and thus enable the gas to get away; but when there were many fathoms of hard strata above the seam, it became impracticable to carry off the gas in that way. A way out of the difficulty was to pack the goaf (which would prevent the formation of cavities by falls, in which gas might accumulate), and, as had already been experienced in Scotland, thus prevent gob-fires.

Mr. W. Cochran Carr (Newcastle-upon-Tyne) said that he had always been under the impression that sparks were not likely to cause an explosion. In the old days they had the flint-mill, and had not found any danger. The discovery that sparks in coal-mines were dangerous was a very serious matter indeed. He had been rather surprised that Prof. Cadman had been able to obtain a light from the sparks from the stone in his experiment; but, after examining the stone, he saw that it was quite an unusual one. He hoped that in the coal-mines in England stone of that dangerous character was not to be found. He would like an opinion from the author with regard to the difference between the sparks that he had produced in his experiment and the sparks produced by the old flint-mill.

Mr. H. W. G. Halbaum (Cardiff) wrote that he was in perfect agreement with the principal conclusion arrived at by the writers of the paper. On the first perusal, indeed, he had had some inclination to regard the paper as a "counsel of perfection"; and, no doubt, most men of sufficiently long and varied practical experience underground would be tempted to regard the paper in that light. Nevertheless, it was equally true that many persons engaged in mining had regularly pooh-poohed the idea that falls of roof could possibly initiate colliery explosions. Bearing that fact in mind, and also remembering that many such men were frequently entrusted with grave responsibilities, it followed that a paper such as that under discussion was calculated to prove of substantial value.

As a practical mining man of long underground experience, he (Mr. Halbaum) thought that the writers stood on absolutely safe ground so far as their principal theorem was concerned. Times out of number he had himself observed sparks—in some

cases practically amounting to flames—produced in the goaf by falls of roof having a character similar to that described in the paper; and hundreds of other practical miners could bear testimony to the same effect.

The approximate analyses of the seam as noted in the paper showed a rather large percentage of sulphur. That seemed suggestive. If the information was available, it would be of interest if the authors could say in what molecular form the sulphur appeared. Was it "free," or was it in combination with other elements? If the latter, what was the character of the compound with regard to the degree of mutual saturation of its elements and consequent chemical stability, and how would that affect its primary point of ignition as sulphur, or its secondary potentialities as a cloud of sulphureous fumes? He had always felt an uncomfortable suspicion that the part played by sulphur in such cases was not by any means so well understood as might be wished, and one hoped to have an authoritative pronouncement on the matter.

He noticed, with some regret, that the writers of the paper had commented with unnecessary severity upon Mr. James Ashworth's "percussion" theory. Perhaps Prof. Cadman would, however, prove to the members that compressed air, considered as a means of transmission of power, could not, by any possibility, develop dangerous heating effects. Or, were the authors prepared to deny the existence of all contributory causes? Because, if they were, it should be pointed out that, under such conditions, the paper might very well have commenced at the appendix and ended there. For, apart from the question of contributory causes, and the statement of bald facts that were already public property, the paper did not advance an inch beyond the position reached 16 years ago, when Mr. Edwards's paper, referred to in the appendix, was communicated to the South Wales Colliery Officials' Association. The next step was to name, investigate, and classify those contributory causes, the presence, or absence, or peculiar groupings of which permitted the "sparks" theory to materialize, or otherwise, in actual explosive phenomena.

Of course, the idea of "air-percussion" was entirely Mr. Ashworth's own, and he (Mr. Halbaum) was therefore under no obligation to defend it. He would, however, take it upon him-

self to deny that it was anything like the ridiculous conception which the authors of the paper had insinuated it to be. With regard to falls in the goaf, he had, as previously stated, seen the fire fly about owing to the "rock-percussion." But, personally, he had never seen any damage done by such sparks, although he thoroughly appreciated their potentiality, and freely accepted the testimony of those who had seen that potentiality pass into the active form. On the other hand, he had frequently seen much damage result from the "air-percussion" produced by such falls, and he was quite prepared to believe that the energy liberated might take on other forms which he himself had never witnessed.

One class of "air-percussion" phenomena might be described. Working the "broken" in the bord-and-pillar system in the North of England under a hard thick sandstone roof, he had more than once or twice known an area of goaf-roof—sometimes amounting to 1,000 square yards or more—remain suspended *in situ* after the coal was removed. Then, as it fell bodily, the consequence was that the blast of displaced air effected as much damage in the roadways of the adjacent workings (blowing out doors, timbers, etc.) as a moderate gas-explosion might have effected. In the face of such occurrences, to say nothing about actual explosions in air-compressors, did Messrs. Stirling and Cadman aver that the potentialities of such happenings were so utterly insignificant as to justify them in pooh-poohing the entire question? Most thinking men had an idea that the law enunciating the mutual convertibility of heat and work might, in some cases, extend even to a problem like that. Mr. Ashworth thought so, and evidently the jury on the case thought likewise, and there were twelve of them.

The interesting fact that ethane (C_2H_6) was detected as a constituent of the Bellevue mine atmosphere proved sufficiently that the framers of the various mining curricula had not yet attained omniscience. For, although this gas had previously been found in mines, the text-books usually ignored the matter altogether. The orthodox list, for instance, of the "gases met with in mines" was undoubtedly very imperfect. He (Mr. Halbaum) had always been puzzled to understand why ethylene (C_2H_4) had never been found in the mine, especially in the neighbourhood of underground fires, and it was equally mys-

terious that "mining experts" had never offered an explanation either one way or the other. It was, however, interesting to know that the authors of the paper had at last accidentally stumbled, as others had done before, on ethane, and, in his opinion, the gas next below in the same series was well worth searching for. Because, if any of such higher hydrocarbons were liable to occur in mine atmospheres, the precautions which might be effective against methane would not necessarily be effective against ethylene, ethane, and other gases standing higher in the same series.

It might also be well to point out that most men of prolonged experience underground, whether that experience had been gained in the shallower mines subject to "black-damp," or whether it had been gained in the deeper mines subject to "fire-damp," would confess to having met at times with atmospheric conditions below ground which could not be explained by the presence of any particular gas named in the orthodox list, nor by any possible grouping of the four gases contained in that list.

Mr. James Ashworth (Vancouver, British Columbia) wrote that he had read very carefully an advance copy of Messrs. Stirling and Cadman's paper, having previously had the advantage of seeing the mine to which the paper referred on several occasions.

As the writer was the individual mentioned by the authors as the advocate of the percussion theory, he (Mr. Ashworth) was surprised to find the authors brushing so completely aside his explanation as to the cause of the explosions at a period in the history of mining when all sorts of what were termed "impossibilities" were being demonstrated as possible by colliery explosions. In addition to the disasters to which reference was made in connexion with the writer, he might now add that of Talk o' th' Hill (officially attributed to a gob-fire which it was afterwards discovered did not exist), and where the question of roof-rock sparks was not taken into account; also Mount Kembla, in New South Wales. Matters of "mystery" such as these needed some better explanation than the mere statement that the suggested reason was impossible.

The next point that occurred to the writer was the reason why the two Inspectors named, who had every advantage to enable

them to arrive at the facts, did not attempt to lead the jury into a correct appreciation of the second disaster? If the writer's memory served him correctly, Mr. Heathcote gave a written certificate, on the day of the second disaster, that the mine was clear from gas. Where, then, did the gas come from which was said to have exploded? The third disaster was undoubtedly an explosion, and the effects on the mine were of a totally different character from those wrought by the two first disasters, but this fact was not dealt with in the paper under discussion. Thus the shoots inside of No. 81 were all swept clean of everything movable, but the so-called explosions at the points marked Nos. 1 and 2 did not yield similar effects. Why was this? The mere statement that an occurrence was impossible was not a sufficient reason to give to a scientific society, and the writer ventured to suggest that the personal element should be eliminated as far as possible.

So far as the writer recollected, no one suggested a fall of roof between shoots 61 and 71, and in no case were the "originating" falls suggested as having occurred at the points marked Nos. 1 and 2.

A considerable point was made of "the unsystematic way in which the work had been followed up," and that the system of ventilation was very deficient. Inferentially, therefore, these factors were cited as being important contributory causes to the disasters. Here, again, the writer would suggest that it should be made plain how these deficiencies might be avoided in future, and in cases where holes could not be frequently put through to the surface. There were unfortunately many inaccuracies in the so-called "facts," among which might be mentioned the following:—(1) that the fan was not running on two occasions; and (2) that Alderson lost his life through the failure of his Dræger apparatus. As a matter of fact, Mr. Strachan came through the "after-damp" with the very apparatus which was said to have failed, and there was nothing wrong with it. Whilst on this subject, the writer might add a fact which was perfectly well known to Mr. Heathcote, namely, that the disaster to the rescue-party was due entirely to the criminal negligence of someone who propped open both the doors in the main level, which for some reason or other were not marked on the plan attached to Messrs. Stirling and Cadman's paper, nor were they mentioned in the

text. As the writer was himself jeopardized by this occurrence, he could not easily forget it, and it was his opinion that if the blown-out and damaged stoppings and shoots had been systematically bratticed, neither Alderson nor the other man would have lost their lives; neither would the Dræger apparatus have been called into use. A third inaccuracy was that fourteen lives were saved by the apparatus. Two men only were saved by it, and two were lost, and therefore the balance was even.

The writer believed, as did everyone at the time of the inquest, that the originating point of both disasters (October 31st and December 9th, 1910) was between shoots 71 and 79, and he had never seen nor heard of coked dust being found at the top part of the mine near the point marked 2 on the plan.

As to sparks being produced by the friction of the rocks in certain parts of the Bellevue Mine, this was not discovered by Mr. Heathcote; but that such sparks might light gas in certain parts of the mine was a recognized fact. There were parts of the mine, however, where this effect was not produceable.

Another very important point in connexion with these disasters, was that there were stores of explosive in powder-boxes, and detonators also, in the mine, and these were not accounted for; in fact, the writer had a strong suspicion that the men (two out of four) who were found in No. 4 cross-pitch were peculiarly burned by the ignition of explosive. One point in connexion with the first disaster was of importance, namely, that where the fall of roof and displacement of a pillar (which was being drawn) took place, there was a missed shot, but whether or not this shot was exploded by the crush could not be ascertained.

The writer was as confident as any man could be that the ignition of coal-dust, demonstrated by the coking or cindering, originated at the lower ends of the shoots between Nos. 71 and 79, and not higher up. Had the paper under discussion given the observed facts in greater detail, then it would have been clearly demonstrated to the majority of the members that the differences were so marked between the effects produced by the third disaster, as compared with those of the two first, that they could not fail to see that the effects of an explosion of gas at the points marked 1 and 2 on the plan would have been similar to those produced by the third disaster; but they were not.

For some length of time the writer had been collecting all the facts that he could obtain in connexion with these disasters, but as the material was too bulky for the *Transactions* of an Institution, he proposed to publish them in pamphlet form, possibly also in association with a consideration of the Mount Kembla disaster in New South Wales, which took place in 1902.

The fact that ethane occurred in mines of the Crow's Nest Pass was certain, and larger percentages than that stated might be found in the more fiery mines of that district. The writer believed that this fact was mentioned in connexion with a sample of dust sent to Dr. Bedson by the writer, and tested by the former.

A point which should not escape notice was that the Bellevue Mine was very much more dusty after the first disaster than before. Also as to the escape of the men from the mine, Nichefore, the motor-man at shoot 104, escaped alive, whereas twenty-one men who grouped themselves around the high-pressure air-charging station at shoot 84 were all suffocated together. Had the air-engines been kept at work, it was practically certain that these men would have survived. The high-pressure engines were at a standstill from 7 until 11 o'clock, and eight men survived at shoot 124, although they were without ventilation or fresh air for that period.

The fact of a wall of rock having been blown out between two ends of No. 4 cross-pitch was not mentioned; had it been, it might have helped the percussion-theory a little. Again, the condition of the dead end of No. 5 cross-pitch was not referred to; had it been, some considerable doubt might have been thrown on the theory of ignitions at the points marked 1 and 2 on the plan.

The writer regretted that he had not time in which to discuss this matter more fully. In conclusion, he would remark, however, that it was much easier to say that an explosion of gas was the cause of the disaster, and without the aid of air-percussion or compression or of coal-dust, than it was to prove the fact of a pure gas explosion. The writer would suggest that the theory set out by the authors of the paper was capable of considerable revision, and that the fall of roof, mentioned by Mr. Heathcote as the originating point of at least one disaster, could not be taken as a mere matter of friction when the mass repre-

sented such dimensions as 500 feet in length, 80 feet in width, and 4 feet in thickness. The displacement of air by such a fall would, the writer suggested, wreak more damage than blow a few feathers about. Would the friction of such rocks as those described in the paper ignite coal-dust without an admixture of gas?

Prof. JOHN CADMAN (Birmingham University), in reply, said that, speaking for Mr. Stirling and himself, they were gratified that the paper had brought forth such an interesting discussion, and that so much data had been put forward supporting sparks from falling rocks as an igniting agent in ignition of inflammable gas. A reference had been made to the "flint-mill," a machine which he understood was abandoned not only because of its meagre lighting power, but also because it was capable of igniting inflammable gas. The experiments which he had just conducted spoke for themselves.

With regard to certain points raised by Mr. Halbaum, he was sorry that his investigations had not elucidated the manner in which the sulphur occurred in the coal, but he agreed with Mr. Halbaum that the subject was one which was worthy of consideration. Mr. Halbaum's attempt to bolster up a percussion theory in face of the facts put forward by the writers was unfortunate. It was perfectly well known to everyone, as could be demonstrated in a simple physical experiment, that inflammable material could be readily ignited by suddenly compressing air in a closed vessel; but the circumstances in the cases under review, the numerous and large roadways, and great cavities, entirely prohibited the introduction of such a theory. It was a simple calculation to show the range of pressures that could be exerted by a fall of roof of dimensions possible at Bellevue, and it was incumbent upon Mr. Ashworth and Mr. Halbaum, if they seriously advanced such a source of ignition, to put forward data upon the point.

He was well aware that damage of a serious character could result from a large fall of roof, and such disturbance was quite consistent with the pressure resulting from such an occurrence. The facts observed at Bellevue were of a totally different nature from those present when large falls of roof occurred, and he had no hesitation in entirely eliminating such a phenomena even as a possible contributory cause.

Mr. Ashworth's contribution to the discussion was not entirely consistent with his evidence as recorded by the shorthand writer at the enquiry, and his attempt to make use of such cases as Talk o' th' Hill and Mount Kembla did not in any way strengthen his contention. He (Prof Cadman) was quite familiar with all the circumstances surrounding the Talk explosion, as he was present during the exploration of the mine immediately after and during the subsequent investigation of the explosion. There was absolutely no doubt as to the origin of the explosion at Talk, as intimated by Mr. Henshaw. He (Prof. Cadman) had detected "gob-stink" soon after the explosion, and was present when the gob-fire was subsequently discovered. The writers could not therefore accept Mr. Ashworth's version of the occurrence, and still adhered to the statements they had made.

He was particularly indebted to Mr. Henshaw for his reference to the work that they were attempting to do at the University, and he would like to take that opportunity of expressing thanks to the coal-owners, particularly the coal-owners of that immediate district, for the great encouragement that they had given in the work. They were, he thought, as fortunate as, if not more fortunate than, any other mining school in Britain, inasmuch as they had in their immediate neighbourhood a set of colliery-owners and mine managers who were always willing to come forward and assist them. Not only had they assisted them in the way that was natural to mine managers and owners, but the coal-owners had placed under their supervision certain work in connexion with the administration of their great industry. They organized and took charge of their mine-rescue arrangements, and they also frequently undertook work for the coal-owners of a nature which they were always very happy and anxious to follow.

The Birmingham University was more than an educational body; they were endeavouring to make the Mining Department a large laboratory which was at the disposal of the coal-owners and managers of the locality; and in any problem which had to be investigated such as a mine manager might have naturally some difficulty in tackling himself, they were always ready and willing to throw the whole of their equipment open to him, either for him to do it himself, or to assist him, or to tackle it

for him. He thanked Mr. Henshaw for his reference to the work which they were doing, and which they would always continue. It was their ambition always to place their equipment at the disposal of managers and coal-owners.

The vote of thanks was carried by acclamation.

The PRESIDENT (Dr. W. E. Garforth) said that they had had a most valuable and instructive paper, and he moved a hearty vote of thanks to the authors.

The Institution of Mining Engineers
Transactions, Vol. 1913

To illustrate Messrs. John T. Stirling and John Cadman's Paper on "The Bellevue Explosions, Alberta, Canada."

Vol. XLV. PLATE XI

FIG. 1.—PLAN OF THE No. 1 SEAM COAL-WORKINGS AT BELLEVUE No. 1 MINE.

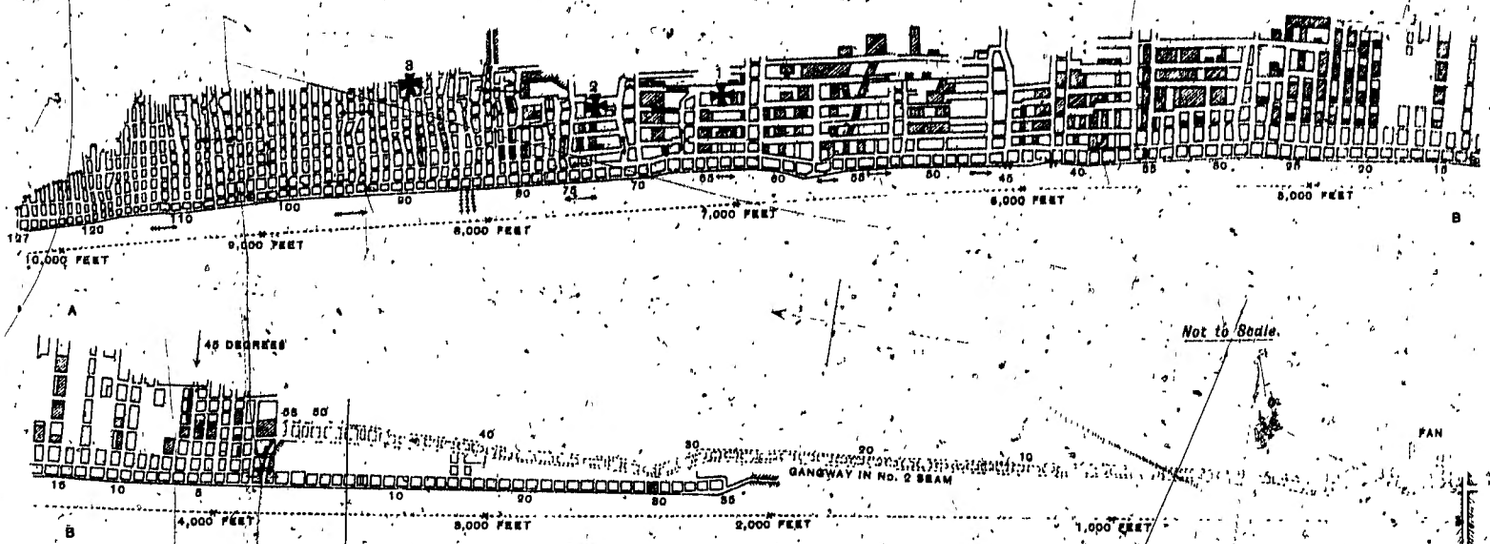

FIG. 1.

REFERENCES.

* INDICATES WHERE MEN WERE AT WORK
\+ " " BODIES WERE FOUND
⟶ DIRECTION OF FORCE OF No. 1 EXPLOSION
⟷ " " " " No. 2 "
⟿ " " " " No. 3 "

FIG. 2.—SECTION OF FALL IN THE UPPER SEAM AT MAINDY PIT, GLAMORGAN.

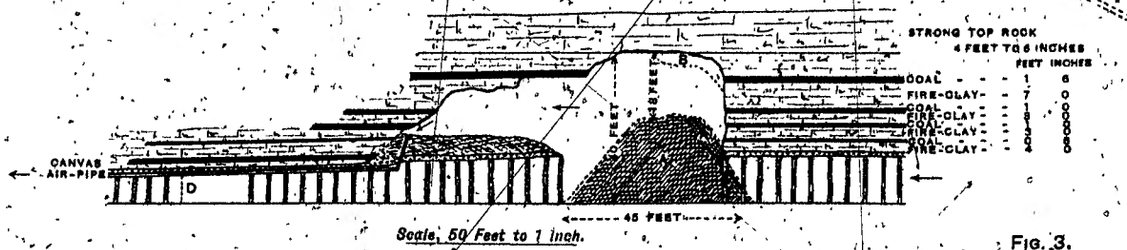

FIG. 2.

REFERENCES.

A FALL ON SATURDAY
A' FALL ON SUNDAY
B PART WHICH FELL
D DOOR

FIG. 3.—PLAN OF THE UPPER SEAM AT MAINDY PIT, GLAMORGAN.

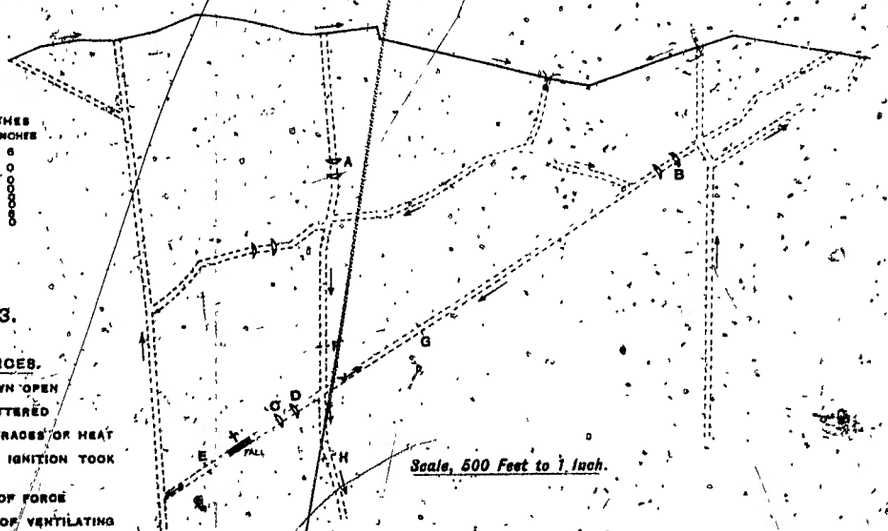

FIG. 3.

REFERENCES.

A B DOORS BLOWN OPEN
C D DOORS SHATTERED
E F G H LIMITS OF TRACES OF HEAT
\+ FALL WHEN IGNITION TOOK PLACE
⟷ DIRECTION OF FORCE
⟶ DIRECTION OF VENTILATING CURRENT

And.r Reid & Comp.y L.d Newcastle upon Tyne

THE INSTITUTION OF MINING ENGINEERS,

COMPRISING THE

Manchester Geological and Mining Society, Manchester.
Midland Counties Institution of Engineers, Derby.
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